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1. Your reference — AUTOSORT

2. Patent application number *(The Patent Office will fill in this part)* — 19 MAR 1999 — **9906326.5**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

TIEDEMANNS-JOH.H.ANDRESEN ANS,
TRADING AS TITECH-AUTOSORT,
JOH. H. ANDRESENS VEI 5,
N-0601 OSLO,
NORWAY.

Patents ADP number *(if you know it)* — 6621395001

If the applicant is a corporate body, give the country/state of its incorporation — NORWAY

4. Title of the invention — INSPECTION OF MATTER

5. Name of your agent *(if you have one)* — ANTHONY BURROWS

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Patents ADP number *(if you know it)* — 3166001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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11. I/We request the grant of a patent on the basis of this application

Signature Anthony Burrows Date
(Anthony Burrows Agent) 19 March 1999

12. Name and daytime telephone number of person to contact in the United Kingdom
ANTHONY BURROWS
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DUPLICATE

ASW-11 / D21

INSPECTION OF MATTER

This invention relates to automatically inspecting matter, for example automatic inspection and sorting of discrete objects of differing compositions, e.g. waste objects, or automatic inspection of sheet material, which may be in the form of a strip, for surface layer composition, e.g. surface layer thickness.

With the recent focus on collection and recycling of waste, the cost effectiveness of waste sorting has become an essential economic parameter.

In the "Dual System" in Germany all recyclable "non-biological" packaging waste excluding glass containers and newsprint is collected and sorted in more than 300 sorting plants.

Objects can be sorted on the basis of:-

Size
Density/weight
Metal content (using eddy current effect)
Ferrous metal content (using magnetic separation)

but most objects such as plastics bottles and beverage cartons are still today sorted out manually to a considerable extent. Some beverage cartons contain an aluminium barrier and by eddy current induction they can be expelled from the waste stream. Generally, beverage cartons in their simpler form present a composite object consisting of paperboard with polymer overcoats on both their inside and outside surfaces.

Several sorting systems exist today that can sort a number of different plastics bottles/objects from each other when they arrive sequentially (i.e. one-by-one). The detection is based on reflected infrared spectrum analysis. To separate the various polymers a quite elaborate variance analysis is performed and thus detection systems become expensive. The objects being fed sequentially pass beneath the infrared spectral detector whereby infrared is shone onto the objects and the relative intensities of selected wavelengths of the infrared radiation reflected are used to determine the particular plastics compound of the plastics passing beneath the detection head.

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Downstream of the detection head are a number of air jets which blow the individual plastics objects into respective bins depending upon the plastics which constitutes the majority of the object.

A similar system is disclosed in US-A-5,134,291 in which, although the objects to be sorted can be made of any material, e.g. metals, paper, plastics or any combination thereof, it is critical that at least some of the objects be made predominantly from PET (polyethylene terephthalate) and PS (polystyrene) as well as predominantly from at least two of PVC (polyvinyl chloride), PE (polyethylene) and PP (polypropylene), for example objects including: an object made predominantly from PET, an object made predominantly from PS, an object made predominantly from PVC and an object made predominantly from PE. A source of NIR (Near Infra Red), preferably a tungsten lamp, radiates NIR onto a conveyor sequentially advancing the objects, which reflect the NIR into a detector in the form of a scanning grating NIR spectrometer or a diode array NIR spectrometer. The detector is connected to a digital computer connected to a series of solenoid valves controlling a row of air-actuated pushers arranged along the conveyor opposite a row of transverse conveyors. The diffuse reflectance of the irradiated objects in the NIR region is measured to identify the particular plastics of each object and the appropriate solenoid valve and thus pusher are operated to direct that object laterally from the conveyor onto the appropriate transverse conveyor. The computer can manipulate data in the form of discrete wavelength measurements and in the form of spectra. A measurement at one wavelength can be ratioed to a measurement at another wavelength. Preferably, however, the data is manipulated in the form of spectra and the spectra manipulated, by analogue signal processing and digital pattern recognition, to make the differences more apparent and the resulting identification more reliable.

DE-A-4312915 discloses the separation of plastics, particularly of plastics waste, into separate types, on the basis of the fact that some types of plastics have

characteristic IR spectra. In the IR spectroscopic procedure, the intensity of diffusely reflected radiation from each sample is measured on a discrete number of NIR wavelengths simultaneously and the intensities measured are compared. Measurements are taken on wavelengths at which the respective types of plastics produce the minimum intensities of reflected radiation. If, for example, three different plastics are to be separated, each sample is measured on three wavelengths simultaneously, whereby one type of plastics is identified in a first comparison of the intensity of the reflected radiation on the lowest wavelength with that of the second-lowest wavelength and the other two types of plastic are determined in a second comparison of the greater intensity on one wavelength in the first comparison with the intensity on the third wavelength. To measure the light on particular wavelengths, respective detectors can have narrow band pass filters for the respective requisite wavelengths, and respective constituent cables of a split optical fibre cable are allocated to the respective detectors, the cable entry lying in the beam path of a lens for detecting the light reflected from the sample. Alternatively, a light dispersing element, e.g. a prism or grid, is placed in the beam path after the lens and several detectors are arranged to detect the NIR of the requisite wavelengths. Sorting facilities are controlled by utilising the detection data obtained by the comparisons. As a further example, five differing plastics, namely PA (polyamide), PE, PS, PP and PETP, may be separated, utilising measurement points at five differing wavelengths between 1500nm. and 1800nm.

EP-A-557738 discloses an automatic sorting method with substance-specific separation of differing plastics components, particularly from domestic and industrial waste. In the method, light is radiated onto the plastics components, or the plastics components are heated to above room temperature, light emitted by the plastics components and/or light allowed through them (in an embodiment in which light transmitted through the components and through a belt

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conveying them is measured) is received on selected IR wavelengths, and the material of the respective plastics components is identified from differences in intensity (contrast) between the light emitted and/or absorbed, measured on at least two differing wavelengths. The light emitted or allowed through is received by a camera which reproduces it on a detector through a lens. A one-dimensional line detector is usable, although a two-dimensional matrix detector or a one-element detector with a scanning facility can be employed. In order that the camera may receive the light on selected IR wavelengths, interference filters may be mounted either in front of the light source or in front of the lens or the detector. In an example in which the material of the plastics components is identified from the differences in intensity of emitted light at two differing wavelengths, the wavelengths are chosen to produce maximum contrast. This means that one wavelength is selected so that maximum intensity of the emitted light is obtained at a specified viewing angle, whereas the other wavelength is selected so that minimum intensity is obtained at that viewing angle. Changing of wavelengths may be achieved by mounting the filters on a rotating disc, with the frequency of rotation being synchronised with the imaging frequency of the detector. Alternatively, an electrically triggered, tunable, optical filter may be employed. The electrical signals generated by the detector are fed to an electronic signal processor, digitised, and subsequently evaluated by image processing software. It is ensured that the plastics components are at approximately the same temperature at the time of imaging, as differences in contrast can also be caused by temperature differences. The belt should consist of a material which guarantees constant contrast on individual wavelengths.

There is also previously known a system in which infrared spectral detection is performed from below the objects, with the objects passing sequentially over a hole up through which the IR is directed. Again, the infrared reflected is used to sort the objects according to the

various plastics within the respective objects.

US-A-5260576 and US-A-5339962 disclose a method and apparatus for distinguishing and separating material items having different levels of absorption of penetrating electromagnetic radiation by utilising a source of radiation for irradiating an irradiation zone extending transversely of a feed path over which the material items are fed or passed. The irradiation zone includes a plurality of transversely spaced radiation detectors for receiving the radiation beams from the radiation source, the detectors receiving the radiation substantially on a direct line from the source. The material items pass through the irradiation zone between the radiation source and the detectors and the detectors measure one or more of the transmitted beams in each item passing through the irradiation zone to produce processing signals which are analysed by signal analysers to produce signals for actuating a separator device in order to discharge the irradiated items toward different locations depending upon the level of radiation absorption in each of the items. The disclosure states that mixtures containing metals, plastics, textiles, paper and/or other such waste materials can be separated since penetrating electromagnetic radiation typically passes through the items of different materials to differing degrees, examples given being the separation of aluminium beverage cans from mixtures containing such cans and plastic containers and the separation of chlorinated plastics from a municipal solid waste mixture. The source of penetrating radiation may be an X-ray source, a microwave source, a radioactive substance which emits gamma rays, or a source of UV energy, IR energy or visible light. One example of material items which are disclosed as having been successfully separated are recyclable plastic containers, such as polyester containers and polyvinyl chloride PVC) containers, which were separated using X-rays. WO-A-95/03139 discloses a similar system which is employed for automatically sorting post-consumer glass and plastics containers by colour.

In an eddy current system for ejecting metal from a

stream of waste, the discharge end roller of a belt conveyor normally contains a strong alternating magnetic field generated by permanent magnets contained within and distributed along the roller and counter-rotating relative to the sense of rotation of the roller. This field ejects metallic objects to varying degrees depending upon the amount and the conductivity of the metal of the object. Since metallic objects in which the metal content is small, for example post-consumer packaging cartons of a laminate consisting of polymer-coated paperboard and aluminium foil, are only weakly affected by the magnetic field, such cartons tend not to be separated-out by the eddy-current ejection system.

Another known system uses an electromagnetic field for eddy current detection through induction of eddy currents in the metal in metallic objects and the detection output is used to control an air jet ejection arrangement but this time the objects are caused to queue up one after another in single lines.

US-A-4996440 discloses a system for measuring one or a plurality of regions of an object to be able to determine one or a plurality of dimensions of the object. In one example, the system utilises a mirror arrangement for transmitting pulsed laser light so that the light impinges downwards upon the object and for receiving the upwardly reflected light. The system includes a laser, a rotating planar mirror and a concave frusto-conical mirror encircling the planar mirror, which serve for directing the light beam towards the object. The frusto-conical mirror, the planar mirror and a light receiver serve for receiving light beams which are reflected from the object. Electronic circuitry connected to the light receiver serves for calculating the travel time of the beam to and from the object, with a modulator causing the light beam to be modulated with a fixed frequency and the rotating planar mirror and the frusto-conical mirror causing the light beam to sweep across the object at a defined angle/defined angles relative to a fixed plane of reference during the entire sweeping

operation.

WO-A-96/06689 discloses a system for automatically inspecting matter for varying composition and comprising one or more detection stations through which one or more streams of matter are advanced and particular materials therein are detected through their diffusely reflected IR spectra, if any, and/or through their variation of an electromagnetic field by their metallic portions, if any. In one version, a multiplicity of detection points represented by lenses are distributed in a straight line across and below the stream as it passes over a transverse slot through a downwardly inclined plate at the downstream end of a conveyor belt, with a separate light source for each lens. Optical fibres transmit the IR from the respective lenses to a rotary scanner whence a diffuser shines the IR onto infrared filters ahead of IR detectors dedicated to respective wavelengths, to date output of which is utilized in controlling air jet nozzles which separate-out desired portions of the stream. In other versions, a row of light sources distributed across the overall width of one or more belt conveyors may cause desired portions of the stream at detection points distributed in an arc across the stream to reflect light diffusely onto a part-toroidal mirror extending over that overall width, whence the light is reflected, by a rotating, polygonal mirror through optical filters dedicated to differing IR wavelengths, onto detectors the data output of which is utilised in controlling solenoid valves operating air jet nozzles which separate-out the desired portions. Alternatively or additionally, an oscillator and an antenna which extends over that overall width generate an electromagnetic field through the belt and sensing coils sense variations therein produced by metallic portions of the stream passing through the detection station and the detection data produced by the sensing coils is used to control the solenoid valves operating the nozzles to separate-out the metallic portions. In a further version, the rotating, polygonal mirrors are retained and the part-toroidal mirror may be replaced by a mirror comprised of a

series of facets or very small mirrors in a horizontal row transverse to the stream, which in this version is a laminate comprised of paperboard onto which a polymer has been extruded. The detection points are arranged in a straight row across the laminate.

According to a first aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to advance through a detection station, emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter at said detection station, wherein said medium is varied by variations in said matter at said detection station, receiving the varied medium either directly, or via a folding mirror, from said matter at a rotary polygonal mirror, reflecting the varied medium from the rotary polygonal mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a second aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station through which said matter advances, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter at said station, a rotary polygonal mirror at said station arranged to receive directly, or via a folding mirror, from said matter detection medium varied by variations in said matter at said station, and detecting means serving to receive the varied medium by reflection from the rotary polygonal mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

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According to a third aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to advance through a detection station, emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter at said detection station, wherein said medium is varied by variations in said matter at said detection station, receiving the varied medium from said matter at a rotary polygonal mirror, said varied medium converging continuously throughout its path from said matter to said polygonal mirror, reflecting the varied medium from the mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a fourth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station through which said matter advances, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter at said station, a rotary polygonal mirror at said station arranged to receive from said matter detection medium which has been varied by variations in said matter at said station and which has converged continuously throughout its path from said matter to said receiving means, and detecting means serving to receive the varied medium by reflection from the mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these four aspects of the present invention, it is possible to simplify and thus reduce the cost of the apparatus compared with a known apparatus in which the varied

medium is received at the rotary polygonal mirror by way of a mirror of a character which is complicated and expensive to produce.

The reflective faces of the rotary polygonal mirror are at least two in number and may be either planar or curved and either substantially parallel or inclined to the axis of rotation of the mirror, i.e. the mirror may be cylindrical or pyramidal.

A particular advantage of the feature that the varied medium converges continuously throughout its path from said matter to said receiving means is that the stream width covered by the receiving means (in the form of the rotary polygonal mirror) can be changed by changing the spacing between the matter and the receiving means, whereby a plurality of arrangements each comprising such receiving means, such detecting means and such data-obtaining means can be disposed side-by-side, particularly in the form of modules, transversely of the stream so that each arrangement inspects part of the width of the stream and the width parts inspected by the respective arrangements overlap each other to desired extents.

According to a fifth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to advance in a feed direction through a detection station, emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter at said detection station, wherein said medium is varied by variations in said matter at said detection station, receiving the varied medium at a rotary polygonal mirror having its axis of rotation at substantially the axis of its polygon and extending in said feed direction, reflecting the varied medium from the mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a sixth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station through which said matter advances in a feed direction, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter at said station, a rotary polygonal mirror at said station arranged to receive detection medium varied by variations in said matter at said station, and detecting means serving to receive the varied medium by reflection from the mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom, said mirror having its axis of rotation at substantially the axis of its polygon and extending in said feed direction.

Owing to these two aspects of the invention, it is possible to simplify and thus reduce the cost of the apparatus compared with a known apparatus in which the varied medium is transmitted to the mirror by way of a part-toroidal mirror or a multi-facetted or similar mirror. Again, the polygonal mirror may be cylindrical or pyramidal.

According to a seventh aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to fall freely at a detection station, emitting a detection medium, which comprises electromagnetic radiation, to be active at the freely falling matter at said detection station, wherein said medium is varied by variations in the freely falling matter at said detection station, receiving the varied medium at detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to an eighth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station at which said matter falls freely, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at the freely falling matter at said station, receiving means at said station arranged to receive detection medium varied by variations in said freely falling matter at said station, and detecting means serving to detect a plurality of wavelengths of said varied medium substantially simultaneously and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the present invention, wherein the matter advances at the detection station in a freely falling condition, it is possible to carry out the detection without needing to take into account the presence of some conveying means and also possible to carry out reflection-reliant detection at a substantially constant spacing between the advancing matter and the receiving means.

By means of a suitable deflector above the region at which the detection medium is to be active, the matter can be caused to fall freely in a curved distribution around a vertical axis, most preferably at a substantially constant radius from that axis.

According to a ninth aspect of the present invention, there is provided a method of automatically inspecting matter for varying composition, comprising advancing a stream of said matter comprised of individual objects, emitting a detection medium to be active at a multiplicity of individual detection zones distributed across substantially the width of said stream at a transverse section of said stream, wherein said medium is varied by variations in the composition of said matter at said transverse section, receiving the varied medium at receiving means, generating detection data in dependence upon the variations in said medium, utilizing a

camera to detect positions of said objects, and generating further data in dependence upon said positions.

According to a tenth aspect of the present invention, there is provided apparatus for automatically inspecting matter for varying composition, comprising detection station means through which a stream of said matter comprised of individual objects advances, emitting means serving to emit a detection medium to be active at a multiplicity of individual detection zones distributed across substantially the width of said stream at a transverse section of said stream at said station means, receiving means serving to receive detection medium varied by variations in the composition of said matter at said section, detecting means serving to generate a first series of detection data in dependence upon the variations in said medium, a camera at said station means and serving to detect positions of said objects and serving to generate a second series of detection data in dependence upon said positions, and data-obtaining means connected to said detecting means and to said camera and serving to obtain the first and second series of detection data therefrom.

Owing to these aspects of the present invention, it is possible simply and inexpensively to sort objects according to their size and/or their composition, as desired.

According to an eleventh aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to advance as a stream through a detection station, emitting a detection medium to be active at said matter at said detection station, wherein said medium is varied by variations in said matter at said detection station, receiving the varied medium from said matter at respective first and second receiving means of respective first and second inspection arrangements, reflecting the varied medium from the first and second receiving means to respective first and second detecting means of said respective first and second inspection arrangements, detecting said varied medium at said first and second detecting means, and generating

detection data from said first and second detecting means in dependence upon the variations in said medium.

According to a twelfth aspect of the present invention, there is provided apparatus for automatically inspecting a stream of matter, comprising a detection station through which said matter advances, emitting means serving to emit a detection medium to be active at said matter at said station, first and second receiving means of respective first and second inspection arrangements at said station arranged to receive from said matter detection medium varied by variations in said matter at said station, and first and second detecting means of said respective first and second inspection arrangements at said station serving to receive the varied medium by reflection from the receiving means, and to generate detection data in dependence upon the variations in said medium, and data-obtaining means connected to said first and second detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the present invention, it is possible to increase the stream width capable of being inspected and/or to improve the resolution of the inspection of the same stream width, in that the inspection arrangements may inspect respective parts of the width of the stream or may each inspect substantially the whole width of the stream. Advantageously, the inspection path of each arrangement is substantially rectilinear and substantially perpendicular to the direction of advance of the stream and, very preferably, the inspection paths are substantially co-incident where they overlap or are directly end-to-end if they do not overlap. It is especially desirable that the inspection arrangements should either commence respective widthwise scans from a common location or terminate respective widthwise scans at a common location. The inspection arrangements may take the form of respective modules arranged side-by-side with each other.

The present invention is applicable to a wide variety of systems of automatically inspecting matter.

By applying multiple sensors and/or a scanning

arrangement, it becomes possible to introduce a large number of detection points.

The detection medium can be electromagnetic radiation, for example IR or visible light, to detect variations in constituency or colour, or an electromagnetic field to detect metal portions of the stream, e.g. in sorting of materials. A wide variety of materials may be sorted from each other, but particularly plastics-surfaced objects sorted from other objects. For the present automatic sorting, the objects must be distributed in substantially a single layer.

For sorting of objects, the objects may be caused to fall freely. Alternatively, they may be advanced through the detection station on an endless conveyor belt. If the objects to be separated-out are plastics objects which are substantially transparent to the electromagnetic radiation, e.g. IR, then the conveying surface of the belt should be diffusely reflective of the electromagnetic radiation.

For a polymer, two or more detection wavelength bands in the NIR region of 1.5 microns to 1.85 microns can be employed. For a laminate comprised of polyethylene on paperboard, a first wavelength band centred on substantially 1.73 microns is employed, as well as a second wavelength band centred less than 0.1 microns from the first band, for example at about 1.66 microns.

The matter may comprise laminate comprised of a first layer and a second layer underneath said first layer and of a material having a spectrum of reflected substantially invisible electromagnetic radiation significantly different from that of the material of the first layer. As a result, the spectrum of substantially invisible electromagnetic radiation, particularly IR, reflected from such laminate can be readily distinguishably different from the spectrum of that radiation reflected from a single layer of the material of either of its layers.

If the stream is a continuous strip of laminate advancing on a laminating machine, for example a polymer

coating machine coating a polymer layer onto a substrate, it is possible to detect any variation in composition of the advancing polymer layer and to correct the coating process accordingly.

Alternatively, it is possible to separate-out objects, e.g. waste objects, of a predetermined composition from a stream of matter, e.g. waste matter, which can be relatively wide compared with a sequential stream, so that a relatively high rate of separation can be achieved.

Typically, there could be a transverse row of some 25 to 50 detection zones for a stream 1m. wide. A central detection system can be applied to "serve" all 25 to 50 detection zones if there is sufficient IR intensity across the width of the stream from a single or multiple IR source or even if there is an infrared source at each detection point. Optical fibres may lead the reflected IR from the detection points to this central detection system. However, a system of IR reflectors is preferred to optical fibres, since a reflector system is less expensive, allows operation at higher IR intensity levels (since it involves lower IR signal losses) and is less demanding of well-defined focal depths. If the stream moves at some 2.5 m/sec. and the system is capable of 100 to 160 scans across the stream each second, then detections can be made at a spacing of some 2.5 to 1.5cm along the stream. When each scan is divided into 25 to 50 detection zones, detections can be made in a grid of from 1.5 x 2.0cm. to 2.5 x 4.0cm. The transverse scanning of the moving stream makes it possible to construct a two-dimensional simulation which can be analysed using image processing. In this way it is possible to detect:

matter composition, e.g. thickness, and position in the stream

shape and size of composition variation

several composition variations substantially simultaneously.

The detection data processing system will determine wanted/unwanted composition at each detection zone.

For food quality control, e.g. fat content and maturing of fish and the maturing of meat, the apparatus measures the quality of the foodstuff by monitoring the absorption spectrum in the IR range.

Although an advantage of arranging the detection of objects from underneath (rather than above) the waste stream is that it gives as uniform a distance from detection point to object as possible, it has disadvantages. By irradiating the waste objects on a conveyor belt with radiation from above and by utilising a reflector system to select that portion of the reflected radiation which propagates upwards, the system can be made very focusing insensitive. The alternative of the stream being in free fall is particularly advantageous in enabling the distance from detection point to object to be as uniform as possible, while avoiding many of the disadvantages of detection from underneath.

In addition to or instead of spectral sensing devices, electromagnetic sensing devices may be employed at a metal-detection station. By means of an antenna extending across the advancing stream, an alternating electromagnetic field can be set up across the stream. By providing as many eddy current detection zones (in the form of individual detection coils) across the stream as there are spectral detection zones a simultaneous metal detection can be performed at very low additional cost. Thereby, with a waste stream including polymer-coated beverage cartons, and with several air jet arrays arranged one after another it becomes possible to sort out:

beverage cartons without an aluminium barrier
beverage cartons with an aluminium barrier
other metal-containing objects.

With a more elaborate spectral analysis it also becomes possible to identify and sort out the type of polymer in a plastics object. The system could hence be applied to sorting into separate fractions the various plastics types occurring.

By employing one-and-the-same detection station for at

least two streams simultaneously, the cost of inspection can be reduced compared with a case where the streams have respective detection stations.

In order that the invention may be clearly and completely disclosed, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 illustrates diagrammatically, in perspective view from above, a system for automatic sorting of waste objects of differing compositions,

Figure 2 illustrates diagrammatically, in front elevation, a modified version of the system, with two rotary polygonal mirrors in respective first angular positions,

Figure 3 is a view similar to Figure 2, but with the mirrors in second angular positions, and

Figure 4 illustrates diagrammatically, in perspective view from above, a further modified version of the system.

The present system utilizes principles of the system of WO-A-96/06689 and reference should be made to the latter for any necessary clarification of the present description with reference to the present drawings.

Referring to Figure 1, a detection station 2 including a vertically downwardly directed video camera 4 and a detection unit 6 identical to one of the two units 6 to be described with reference to Figures 2 and 3 has a stream of waste matter, including objects 14 such as containers, advanced therethrough on a substantially horizontal conveyor belt 8 to a transverse array of air jet nozzles 10. The rectangular picture area of the camera is indicated at 12 and spans the whole width of the belt 8 and thus of the stream of waste. The data from the camera 4 is used to identify the positions of individual objects in the waste stream (in the sense of approximately the region that the object occupies in the stream of waste). The unit 6 scans the stream of waste along a rectilinear path P also extending the whole width of the belt 8 and thus of the waste stream, the path P being perpendicular to the longitudinal direction D of the belt 8, i.e. to the feed direction of the waste stream. By infrared spectrum analysis, the unit 6 detects the composition of at

least some of the objects 14 in the waste stream. The data from the camera 4 and the unit 6 are used to control a controller 16 for solenoid valves (not shown) which control the supply of compressed air to the respective nozzles 10. In this relatively simple system, the composition and/or colour of each object is/are detected by the unit 6, whilst the camera is used to monitor the scanned region and its data output employed automatically to detect the positions of the objects and to correct the data relating to those objects as received from detectors 21 in the unit 6. The belt 8 may be 0.5m. wide and the camera 4 and the unit 6 be active over the whole width of the belt.

Referring to Figures 2 and 3, the units 6 are arranged side-by-side above the conveyor belt 8 which, in this version, may be 1.0m. wide. Each unit includes a housing 18, of which the front cover has been removed from the left-hand unit in Figures 2 and 3. Each housing 18 contains a mounting bracket 20. The detection station 2 differs from the detection station 131 of the version of Figure 11 of WO-A-96/06689 chiefly in that there are two units 6 disposed side-by-side and that, in each unit 6, the cylindrical, polygonal mirror 108 of that Figure 11 has been re-orientated such that its axis of rotation R now extends in the feed direction D (such mirror being referenced 19 in the present drawings). Not only does this change simplify the path of transmission of the varied IR radiation from the stream of matter to the filter/detector combinations 21, but the loss of IR intensity produced by such a relatively long path as in that Figure 11 can be minimised. The filters/detectors 21 are parts of an optical detection device 22 which includes a beam splitter 24 and is mounted on the bracket 20. Also mounted on the bracket 20 is a microprocessor 26 which receives the data output from the filter/detectors 21 (and from the camera 4 if provided) and data as to the angular position of the rotating polygonal mirror 19 and controls accordingly the controller 16. The polygonal mirrors 19 rotate in the senses of the arrows A and the starting path of the diffusely reflected IR via each mirror 19 to its associated beam splitter 24 at the

commencement of a scan is indicated by the dot-dash line S and its finishing path at the end of the scan is indicated by the dot-dash line F. One unit 6, or a row of at least two units 6 side-by-side, is/are applicable not only to material being advanced by a conveyor belt, but also to material advancing down a slide or to material advancing in free fall. With the three filter/detectors 21 shown, the unit 6 is able to perform simultaneous analysis of three wavelengths of electromagnetic radiation. At least three wavelengths and thus a corresponding number of filter/detectors are chosen if IR is used as the detection medium, in order to detect composition of the matter, or two wavelengths and thus two filter/detectors in the event that visible light is chosen as the detection medium, in order to determine the colour of the matter. The polygonal mirror gives relatively high scanning speed with relatively moderate rotational speed of the mirror. The radiation reflected from the matter over the scanning width is converging.

The spacing between the or each polygonal mirror and the stream of matter is kept as small as practical, in order to maintain high resolution and intensity of reflected radiation with relatively low illumination intensity.

Compared with, for example, the detection system of Figure 11 of WO-A-96/06689, the system of the present Figures 2 and 3 allows a higher resolution and a somewhat better signal-to-noise ratio to be obtained. Moreover, the distance which the reflected radiation has to travel from the matter to reach the filter/detectors 21 can be relatively reduced by up to one half, so reducing light transmission losses, which can be quite significant if the reflected radiation has to travel through a polluted, e.g. dusty, atmosphere and/or indirectly via an intermediate mirror.

Parallactic and shadowing effects can be kept within tolerable limits for objects less than, e.g. 200mm., tall if the transverse angle of reflection can be kept within some 30° from the vertical. During each scan, the reflection point on the polygonal mirror will move over the surface of the mirror in the direction of scan, which somewhat reduces the

angle of reflection towards the end of the scan.

With an hexagonal mirror, for example, a new scan will start upon 60° rotation of the mirror. However, each scan requires somewhat less than half of that 60° rotation to be completed, and thus an interval probably longer than the actual scan period exists in which, for instance, some detector calibration can be undertaken. However, the spectral analysis and two-dimensional simulation of the stream are largely carried out in parallel with the data acquisition, which is practically continuous.

An average minimum object height of, for example, 3cm. may be pre-set as a reference to correct for some of the parallactic error.

It is advantageous to have a slight overlap of the inner ends of the widths scanned by the two units 6, in order to avoid inadvertent failure to detect objects or parts of objects in the border zone. Each unit 6 operates independently of the other, even to the extent of controlling its own array of air jet nozzles (not shown).

Referring to Figure 4, waste matter advanced by a feed conveyor belt 30 inclined downwardly at a slight angle β to the vertical drops onto a conical or elliptical deflector 32 so that the waste becomes distributed at a substantially constant radius about a vertical axis V of the deflector 32. Below the deflector is a housing 34 having its front wall 34a substantially coaxial with the axis V and formed with a horizontal slot 36 also co-axial with the axis V and at the same level as a cylindrical, rotary, polygonal mirror 19 co-axial with and rotating about the axis V, and as an optical detection device 22. The housing 34 also contains lamps 38 for illuminating the matter falling freely past the slot 36. Radiation reflected from the falling matter is then reflected to the mirror 19, which scans the falling matter at a substantially constant distance from the matter in the horizontal plane of the slot 36. Arranged below the housing 34 are a number of air jet nozzle arrays 40 arranged parallelly with the slot 36 at substantially the same radius

from the axis V. Arranged radially outwardly beyond the falling matter are a number of collector shields 42 spaced radially outwardly from each other. The greater its radius from the axis V, the higher the shield 42 extends.

In use, the composition of the matter falling past the slot 36 and/or the relative position of objects 14 falling past that slot is/are detected and the nozzles of the arrays 40 activated accordingly, to sort the objects 14 into the spaces among the shields 42 and at the outside of the outermost shield 42, the remainder of the matter simply continuing to fall vertically to the inside of the innermost shield 42.

The downward inclination of the belt 30 is provided to promote downward acceleration of the matter as it leaves the belt. This downward acceleration increases vertical speed of the matter and thereby the capacity of the apparatus. It may also be advantageous to have a relatively large radius of the front end roller 44 of the belt conveyor to promote such downward acceleration and to reduce rolling of the objects 14.

Use of the deflector 32 promotes distribution of matter into a freely falling distribution co-axial with the axis V. This has the advantage that, because the mirror 19 is also co-axial with the axis V, no significant parallactic error arises. Instead of the lamps 38 being mounted within the housing 34, they may be mounted exteriorly thereof.

In the version of Figure 4, the detecting means, the illuminating means and the ejecting means can be assembled as a single unit. It is believed that ejection of more than one fraction of the matter is feasible at different levels as the matter is falling. However, monitoring by camera may be required to give more precise ejection, especially if more than two desired fractions are to be ejected.

The system of Figure 4 has a particular advantage in that it can occupy less floor area than an equivalent horizontal system.

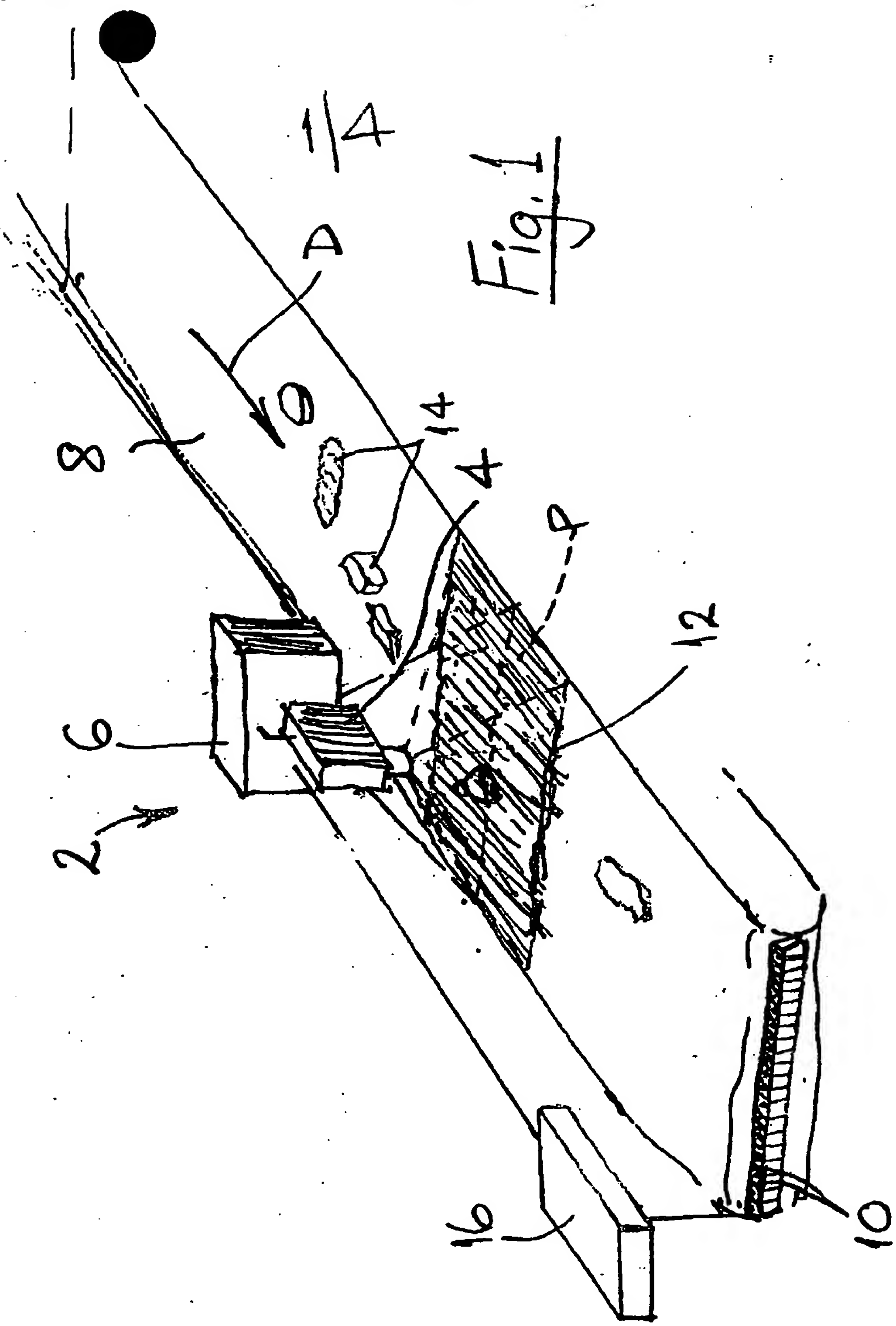
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Fig. 1
A
8
10
14
4
P
12
6
2
16
10

Fig. 2

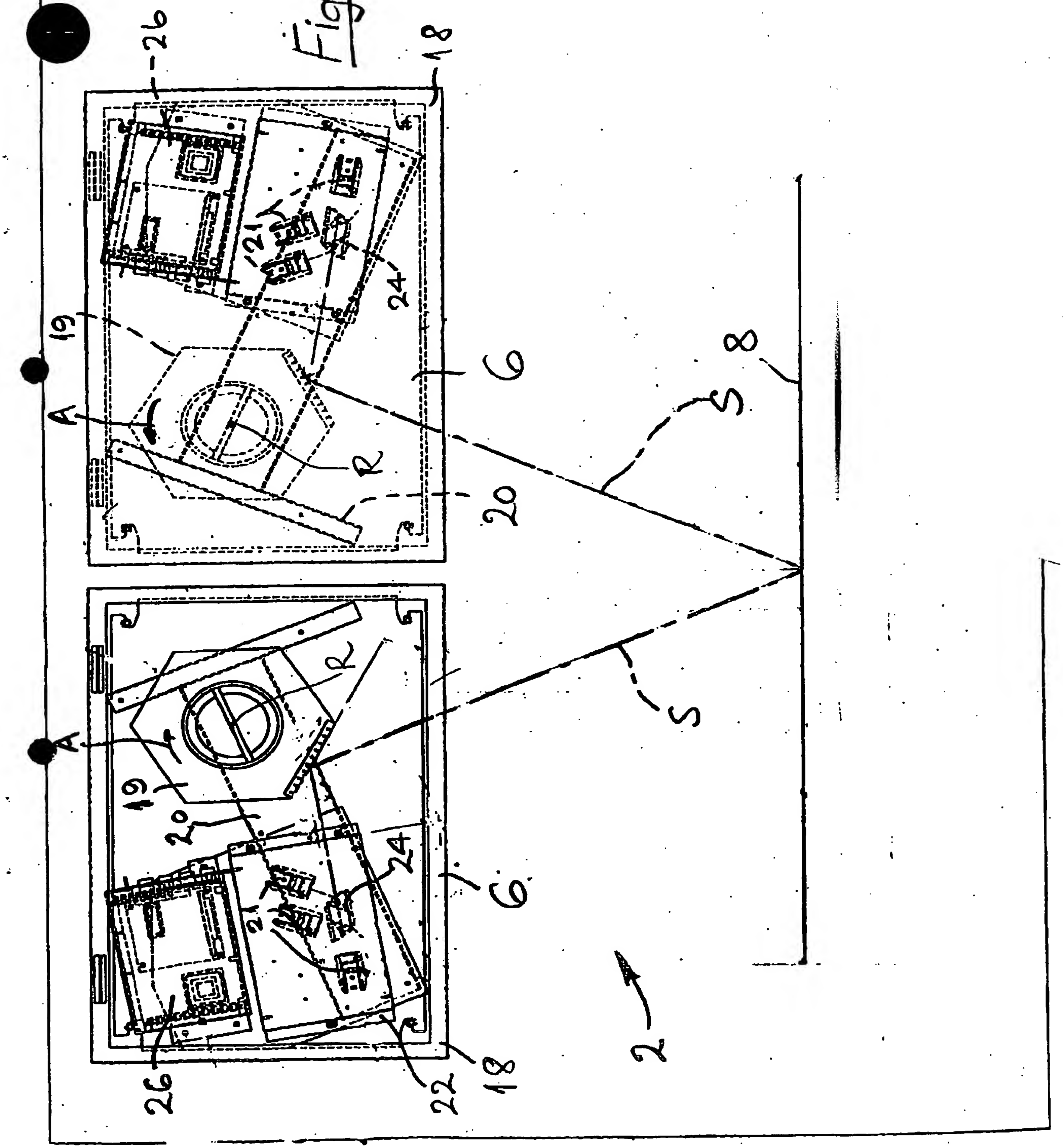
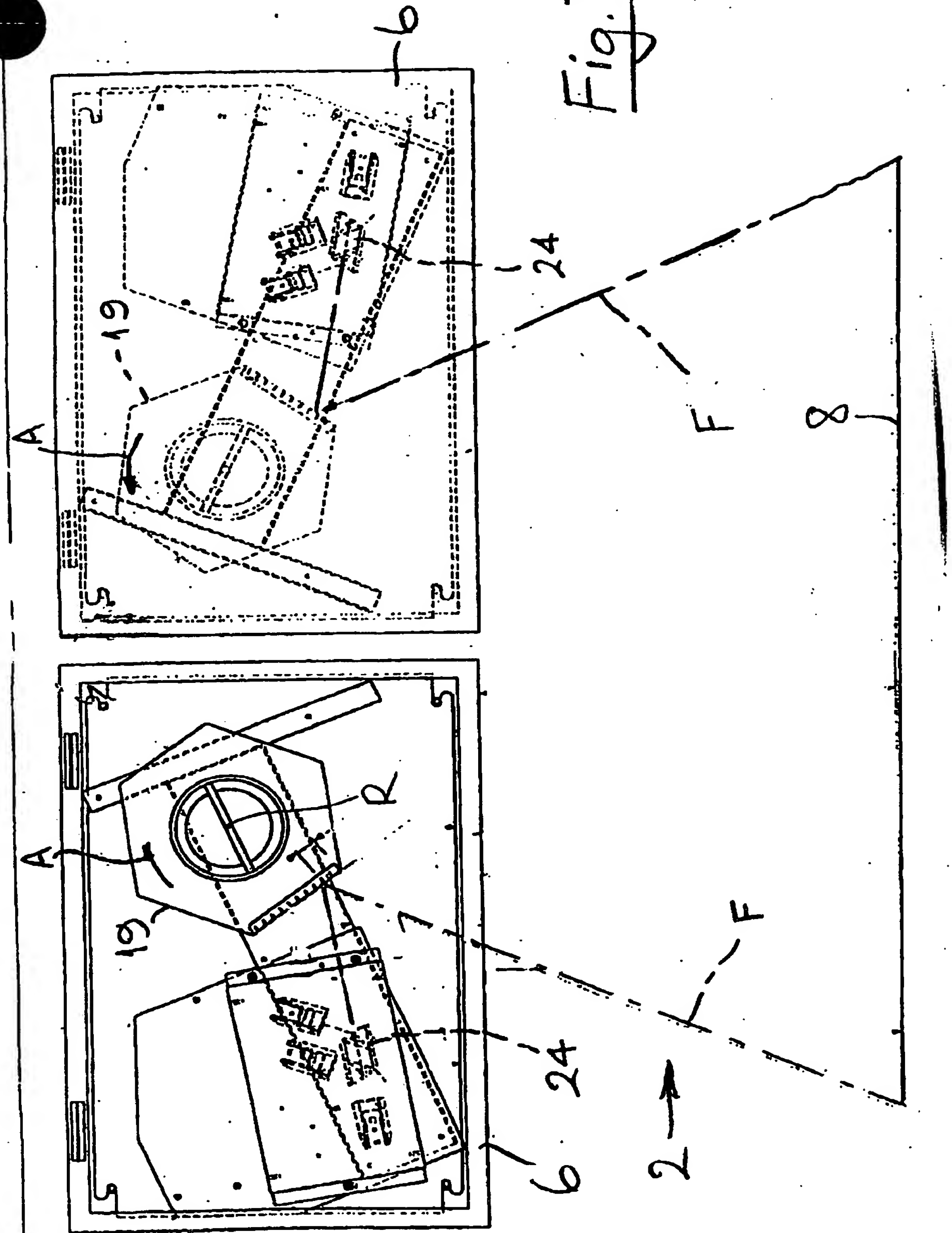


Fig. 3



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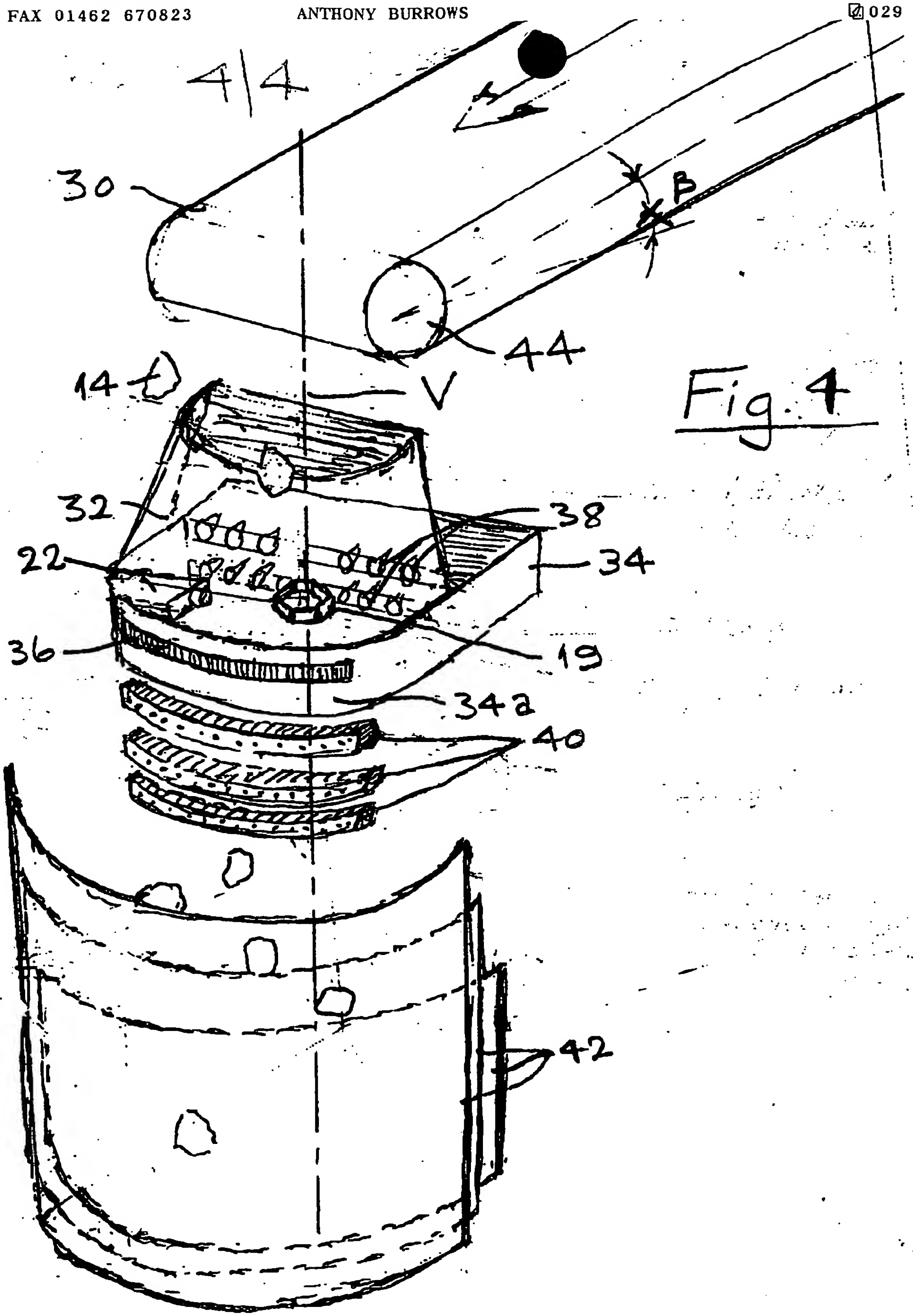

Fig. 4

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